SCIENCE

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MSS. intended for publication and books, etc., intended for review should be sent to Professor J. McKeen Cattell, Garrison-on-Hudson, N. Y.

NATIONAL ACADEMIES AND THE PROGRESS OF RESEARCH

I. THE WORK OF EUROPEAN ACADEMIES

THE Academy of Plato, who bequeathed to his followers the walled garden and appointments in the place named after the hero Hekademus, was at once a school of instruction and a society for the development of new knowledge. Here he discussed his philosophy with associates and students, while it was still in the making, thus bringing them under the stimulating influence of fresh thought, developing and expanding from day to day. Writing of the Old Academy, which included the schools of Plato and his immediate successors, Cicero remarks:

> Their writings and method contain all liberal learning, all history, all polite discourse; and besides they embrace such a variety of arts, that no one can undertake any noble career without their aid. . . . In a word the academy is, as it were, the workshop of every artist.[1]

The Old Academy was thus the predecessor of our modern academies of science and of our universities as well. Its world-wide influence, while of course primarily due to the brilliant thinkers of the day, may certainly be ascribed in part to the fact that its instruction was given in an atmosphere charged with the stimulus of original thought and constantly broadening ideas. The great success of the German universities, and the outflow from them of the spirit of research into every phase of German life and thought, is undoubtedly due in the largest measure to the application of this principle. Fortunately for the intel-

[1] Cicero, ''De Fin.,'' Vol. 3, as quoted in the Encyclopædia Britannica, 11th edition, Vol. 1, p. 106.

lectual advancement of the United States, the recognition of its importance has already permeated most of our advanced schools, and is rapidly gaining ground in the minds of their governing boards of trustees.

Aristotle, called by Plato "the mind of my school," came from a family of physicians, and thus inherited a taste for experimental knowledge. To him we owe the beginnings of exact science and the organization of research on a large scale. Thanks to his influence with his pupil Alexander the Great, he was able to command the immense sum of eight hundred talents for the purchase of books and other expenses involved in the preparation of his treatise on zoology. More than this, a thousand men throughout Asia and Greece studied under his direction the life and habits of birds and beasts, fishes and insects.[2] The territories conquered by Alexander were carefully surveyed, by measuring the position of terrestrial objects with respect to stars.[3] Although Aristotle maintained the fixity of the earth, and supposed comets and the Milky Way to be in its higher atmosphere, his reasoning in many astronomical problems was sound, as when he concluded that the earth must be spherical because its shadow on the eclipsed moon is always curved.[4] Thus his studies of natural science foreshadowed the work of the present-day investigator and led to the most far-reaching results.

After his time a gradual division of labor ultimately separated investigations in natural science from the speculations of the philosophers. In Sicily, Egypt and the islands of the Mediterranean true scientific research, in the strictly modern sense, developed with remarkable rapidity, while in the old Lyceum at Athens the philosophy of reasoning and dialectics, caring little for physical causes, was devoted exclusively to the soul.

A deep-seated belief that the senses are deceptive, and the natural impatience of the Greeks, inclining them toward reasoning and speculation rather than the slow and laborious processes of observation and experiment, had first to be overcome.[5] But in the third century B.C. the greatest geometer of antiquity, Archimedes, taught at Syracuse a system of astronomy closely resembling that of Copernicus, founded the science of mechanics in his treatise "De Æquiponderantibus," and devised some of the fundamental experimental methods of modern physics. At the same period Aristarchus of Samos made a first determination of the distance of the sun from the earth and held that "the center of the universe was occupied by the sun, which was immovable, like other stars, while the earth revolved around it."[6] This view was also taught by Seleucus the Babylonian, but it was rejected by Ptolemy, the most celebrated astronomer of his day.

Of all the ancient prototypes of the modern academy, the great Museum of Alexandria holds the first place. Founded by Ptolemy Soter, whose preference would have confined its work to the moral and political sciences, its scope soon expanded under the influence of Ptolemy Phila-

2 Wheeler, "Alexander the Great," p. 37. The strict accuracy of these assertions, which were made by several classical authors, is questioned by Grote and also by Humboldt, who nevertheless concede that Aristotle received from both Philip and Alexander the most liberal support in procuring immense zoological material from Grecian territories and in the collection of books. "Cosmos," Sabine's trans., Vol. II., p. 158.

3 Bossut, "Histoire des Mathématiques," Vol. 1, p. 116.

4 *Ibid.*, p. 117.

5 Weber, "History of Philosophy," Thilly's trans., p. 133 *et seq.*

6 See Humboldt, "Cosmos," Vol. II., p. 309, and notes, p. cix.

delphus and the pressure of circumstances, until it embraced the whole field of knowledge.[7] Here almost all of the important results of Greek science were obtained in a period covering nine centuries. The museum established by Ptolemy was an extensive palace, housing the brilliant company of scholars and investigators gathered together from all parts of Greece. As a state institution, endowed with special revenues, it was under the direction of the government, which appointed its head. This, in accordance with the traditions of the day, was a priest, whose ecclesiastical office, and even the name of the museum itself, gave a kind of religious character to the institution,[8] though it subsequently became purely secular.

Ptolemy Philadelphus collected strange animals from many lands, and sent Dionysius on exploring expeditions to the most remote regions.[9] But while the investigators of the museum doubtless profited by these collections and explorations for their studies in natural history and geography, Matter finds no evidence that at this period the museum possessed either a distinct natural history collection or a zoological park,[10] though the study of medicine was encouraged, and a great art collection was developed.

The rising tide of science soon brought all the material requisites of research, supplementing the great library of 700,000 volumes by the instruments, laboratories and collections demanded by the astronomer, the physicist and the student of biology. A botanical garden, a zoological menagerie, an anatomical laboratory and an astronomical observatory in the Square Porch, provided by Ptolemy Euergetes with an equinoctial and a solstitial armillary, stone quadrants, astrolabes and other instruments, illustrate the nature of the extensive equipment provided. The work of the Alexandrian school thus continued to grow, until it embraced all of natural and physical science, medicine, mathematics, astronomy and geography, history, philosophy, religion, morals and politics. It is significant that an institution which in many respects would be regarded as a model to be striven for to-day, should have developed at so early a period in the history of civilization.[11]

To the Alexandrian school we owe the "Geometry" of Euclid, and his treatises on "Harmony," "Optics" and "Catoptrics"; the hydraulic screw and some of the mathematical and physical discoveries of Archimedes of Syracuse, who spent part of his time in Egypt; the mathematical, astronomical, geographical and historical investigations of Eratosthenes, who first endeavored to determine the circumference of the earth by measuring the difference of latitude and the distance between Alexandria and Syene, and wrote on such subjects as the geological submersion of lands, the elevation of ancient sea-beds, and the opening of the Dardanelles and the Straits of Gibraltar; the "Conic Sections" of Apollonius; the mathematical and astronomical researches of Hipparchus, whose discovery of the precession of the equinoxes was based on observations made five hundred years previously by Timochares at Alexandria; and the great "Syntaxis" of Ptolemy, translated as the "Almagest" by the Arabians, which stood as a commanding authority in Europe for nearly fifteen hundred years. Founded on the geocentric hypothesis, the "Almagest" is nevertheless

[7] Matter, "Histoire de l'Ecole d'Alexandrie," 2d ed., Vol. II., Introduction, p. v.

[8] *Op. cit.*, Vol. I., pp. 87 and 96.

[9] *Ibid.*, p. 158.

[10] *Ibid.*, p. 159.

[11] Draper, "Intellectual Development of Europe," Vol. I., p. 188.

replete with astronomical methods and observations of the widest range and significance, and includes Ptolemy's discovery of the lunar evection, a rough determination of the distance from the earth to the sun, a masterly discussion of the motions of the planets, and a catalogue of 1,022 stars. These remarkable advances, which include only a fraction of the enormous scientific product of the Alexandrian school, were supplemented by equally striking contributions to literature and art. Philology, criticism and the history of literature became sciences, while the coming together of Buddhists, Jews, Greeks and Egyptians, with the most diverse beliefs, led to the development of comparative theology. Of the literary works of the Alexandrian school the Septuagint and the poems of Theocritus are perhaps the most widely known.[12]

The rising power of Rome, which finally made of Alexandria a mere provincial town, was coincident with the decline of Greek intellectual life. In this paper only the more significant epochs in the development of academies can be mentioned, and we must pass over the work of the immediate successors of the Alexandrian school in Rome and Byzantium, and the achievements of Arabian science in Africa, Spain and Persia. In 1453, by the fall of Constantinople, where Greek scholars had preserved, in antiquated and pedantic form, the literary and philosophical traditions of the Alexandrian age, Italy was once more raised to its old position of "Magna Græcia." Some years earlier the scholar and ambassador Pletho, aided by Cosimo de Medici, had established a Platonic academy in Florence. Under this stimulus, and the influence of the Greek refugees, philosophy became popular, and Greek was widely studied. The voyages of Columbus, Da Gama and Magellan, and the astronomical achievements of Tycho Brahe, Copernicus, Kepler and Galileo reawakened the appreciation of scientific research and its possibilities. Leonardo da Vinci continued the work of Archimedes and the Alexandrian school in optics, mechanics and other branches of physics, Vesalius established human anatomy on a firm foundation, and Harvey proved the theory of the circulation of the blood. It is not surprising that under such conditions academies of literature and science should multiply in Europe.

Among the earliest Italian academies were the academy of history, philology and archeology, founded in Rome by Pomponio Leto in 1457; the Accademia di S. Luca, devoted to the fine arts, established in 1577; and the Accademia della Crusca, founded in 1582, which has published several editions of its great Italian dictionary.[13] In addition to these organizations seriously devoted to the encouragement of literature and the arts, a host of imitations sprang up all over Italy during the sixteenth century. Perhaps the gaiety of their proceedings was considered to find sufficient warrant in the splendid suppers offered to the academy of Pomponio by the wealthy German Goritz, regarding which Ginguéné[14] quotes the remarks of an earlier authority:

> Ainsi, dit avec un juste sentiment de regret, le bon Tiraboschi, ainsi parmi les verres et les jeux d'esprit, on cultivait joyeusement les lettres, et les plaisirs mêmes servaient à en encourager et à en ranimer l'étude.

According to Libri,[15] Leonardo da Vinci founded and directed the first scientific and experimental academy established in Italy.

12 See the works of Matter, Montucla, Bossut, Whewell, Draper and Weber.

13 Carutti, "Breve storia dell'Accademia dei Lincei," p. 157.

14 Ginguéné, "Histoire literaire d'Italie," Vol. 7, p. 353.

15 "Histoire des sciences mathématiques en Italie," Vol. 3, p. 30.

Another early academy devoted to the pursuit of science was the Academia Secretorum Naturæ of Naples, which dates from 1560.

Of special interest to the modern investigator is the Accademia del Cimento, which possessed a large collection of physical instruments, many of which are now preserved in the Galileo Museum at Florence. The "Saggi di Naturali Esperienze" made in the laboratories of this institution is an admirably illustrated account of early academic activities. The experiments, which are described in great detail, with the aid of excellent woodcuts of instruments, are in some cases attributed to Galileo, Torricelli and other investigators, and in other cases are said to have been first performed in France. They include a wide variety of subjects, such as the effects of artificial freezing on various waters, wines, acids and oils, the compression of liquids, various phenomena in a vacuum, the electrical properties of amber, and the motion of projectiles.

This important volume was published in 1666, ten years after the establishment of the Academy, which lasted only during this period. The one great Italian academy of science which still survives is the Accademia dei Lincei, founded by Federico Cesi in 1603. His vast plans of organization for the Academy, resembling those of the religious and military orders of the day, are described in an unpublished work entitled the "Linceografo." The Academy was to comprise establishments in the four quarters of the world, where the members would lead a common life in the midst of libraries, museums, observatories, laboratories and botanic gardens, provided with every requisite means of research, and in constant communication with the other constituent bodies of the organization. The name *Lincei*, or Lynx-eyed, was taken in recognition of the reputation of the lynx for extreme penetration of vision, "*vedendo non solo quello che è di fuori, ma anche ciò che dentro si asconde.*"[16]

After a stormy period of youth, during which Cesi and his three fellow organizers underwent many vicissitudes, the Academy was vigorously revived in 1609. Two years later, to its lasting renown, it was joined by Galileo, whose earliest telescopic discoveries had just been made. Under this stimulus, and aided by the widespread interest in Galileo's work, the Academy now advanced rapidly. While devoting special attention to the mathematical and physical sciences, it did not neglect the cultivation of literature, counting among its members historians, poets, antiquarians and philologists. Its cosmopolitan character is indicated by the diverse nationality of its membership, which was drawn from many of the nations of Europe. An English member of this period was Francis Bacon.[17]

In November, 1612, Galileo communicated his discovery and observations of sunspots, which were published by the Academy under the title "Istoria e Dimostrazioni intorno alle Macchie Solari." The manuscript of this epoch-making discovery is still preserved by the Academy. This was followed in 1622 by his "Saggiatore," published in great haste, to avoid interference from the Church. Two years later he demonstrated at Rome the use of the microscope, so named by Fabri, a member of the Lincei. In 1629 Galileo completed his dialogue on "Due massimi sistemi del Mondo," and proposed to go to Rome to see it through the press.

Limitations of space forbid mention of

16 Carutti, "Breve storia dell'Accademia dei Lincei," p. 8.

17 Carutti, *op. cit.*, p. 26.

18 *Ibid.*, p. 28.

the memorable events of this period, in which the Academy supported Galileo in his difficulties with the Inquisition, and accepted the resignation of Valerio, who had attacked his doctrines. It was a stirring period, full of new and vigorous thought, which sharply conflicted with the traditions of a vanishing age. Led by such men as Cesi, Porta, Galileo and Colonna, the Lincei played a prominent part in the development of the scientific advance of Italy and in the cultivation of the growing love of truth which spread throughout the civilized world. But in 1830 the Academy came to a sudden end, attributed by Carutti to the withdrawal of the patronage of Cardinal Barberini.[19]

Since that date it has seen several revivals, which are described in the history from which the present notice is derived. Reconstituted under Victor Emmanuel II. in 1875 as the Reale Accademia dei Lincei, it now flourishes as the national academy of Italy. The class of physical, mathematical and natural sciences has 55 members, 55 national correspondents, and 110 foreign members. The class of moral, historical and philological sciences has 45 members, 45 national correspondents and 45 foreign members. The president belongs to one class, the vice-president to the other, and each has a secretary and an assistant secretary.[20]

The home of the Lincei in the Palazzo Corsini is admirably adapted for the purposes of an academy. The collections include an extensive library, rich in rare books and manuscripts, and a large gallery of paintings, most of which is open to the public. The annual meeting, held in the great hall of the palace, is a very impressive function, attended by the King and Queen and other members of the royal family, whose keen and intelligent interest in the work of the Academy is a powerful incentive to increased effort and broader usefulness.

A brilliant and inspiring picture of the Paris Academy of Sciences at the zenith of its development and fame may be found in the opening chapter of Merz's "History of European Thought." This Academy organized through the efforts of the far-seeing statesman Colbert, at the period when Newton was engaged in the composition of his "Principia," has probably exerted a more favorable influence on the progress of science than any other similar institution in Europe. Enjoying both the moral and financial support of the French government, and permeated by an enthusiasm for scientific research which led its members to develop the most extensive cooperative projects, it offers a pattern which other academies may well seek to imitate. Great as it remains to-day, the period in its history which deserves our most careful consideration is that brilliant epoch, at the end of the eighteenth century, when France was everywhere recognized as the leader of the scientific world.

The academicians named by Colbert held their first informal meeting in the library of the Hotel Colbert in June, 1666. In the words of Fontenelle, heaven seemed to favor the rising company, which was fortunately able to observe two eclipses within the short interval of fifteen days. The second of these was observed with the aid of an instrument devised by Huygens (who was one of the members), and perfected later by Auzout and Picart—the well-known micrometer of the astronomer.

The original group, composed wholly of mathematicians and astronomers, was soon enlarged to sixteen, through the addition of Claude Perrault, Mariotte and other well-known chemists, physicians and anatomists. Laboratories and collections were

19 *Op. cit.*, p. 97.

20 See revised statutes, Carutti, *op. cit.*, p. 245.

established in the Bibliothèque du Roi, and the astronomical instruments were mounted in the garden, awaiting the completion of the great observatory designed by Perrault, where some of the meetings were subsequently held. Picart undertook the measurement of an arc of the meridian which, when completed by Cassini, removed the last doubt of Newton as to the theory of gravitation. He was also sent to Denmark to determine the position of the ancient observatory of Tycho Brahe. Geographical maps were corrected and the latitudes and longitudes of a great number of points were measured. Richer went to Cayenne to determine the length of the pendulum and to make other observations. In short, the greatest activity reigned under the personal stimulus of Colbert, whose correspondence shows how large an amount of time he devoted to the interests of the Academy. Well-known names were added to the list of members, including those of Roemer, who determined the velocity of light from the eclipses of Jupiter's satellites; Cassini, the first of a remarkable lineage of astronomers; the anatomist du Verney; and the great Leibnitz.

Under Louvois, the successor of Colbert, the Academy languished, but Bignon's plan of reorganization, adopted in 1699, inaugurated a new period of progress. The Academy was provided with quarters in the Louvre, where it remained until Napoleon assigned to the Institute the former College Mazarin which it still occupies. Its unpublished memoirs were promptly printed, and were so favorably received by the public that as many as three editions were sometimes demanded. At this period a class of "associés libres" was established, to which such men as Turgot, the engineers Perronet and Belidor and Bougainville the explorer have since belonged.

During the eighteenth century the Academy attained a height only surpassed during the brilliant epoch following the Revolution. Among the important events of this century were the mathematical researches of Clairaut and d'Alembert; the expeditions of Clairaut and Maupertuis to Lapland and of Godin, Bouguer and La Condamine to Peru, for the measurement of arcs of the meridian; the similar undertaking of La Caille at the Cape, where he also determined the lunar parallax in cooperation with astronomers in the northern hemisphere; and the observations of the transits of Venus in 1761 and 1769 by Pingré at Rodrigues' Island, LeGentil in India, and Chappe in Siberia and California. The Cassinis continued their extensive astronomical and geodetic investigations in France, where the activity of astronomical research is illustrated by the fact that when Bernouilli came to Paris in 1760 he found, in addition to the original observatory, eight or ten other observatories engaged in investigation under the direction of academicians. Lalande, known as a severe critic, wrote in 1766:

> The collection of Memoirs of the Academy of Sciences is the richest storehouse of astronomical knowledge which we possess.

But the work of the Academy was by no means confined to astronomy and its sister sciences. Through the investigations of its chemists, the way was prepared for the creation of modern chemistry by Lavoisier. Réaumur, Buffon and their contemporaries were making extensive contributions to natural history, while Haüy was laying the foundations of mineralogy. At the same time Geoffroy and the three Jussieus shared with Linnæus the honor of creating the science of botany.

Under such conditions it is not surprising that the nation should turn to the Academy for assistance and guidance in many of its enterprises. Ministers, parliaments,

administrators and state assemblies often sought its aid and accepted its decisions. So commanding was its position that when all the academies were suppressed under the Revolution, it was stipulated that the Academy of Sciences should provisionally continue its functions and receive its annual revenues from the state.

As there are still those who see in a national academy a menace to true democracy, and who criticize our own National Academy on this score, the attitude of the revolutionists toward the Paris Academy is not without interest. In the report on public instruction made by Talleyrand to the National Assembly in 1791, on behalf of the committee, it was proposed to establish a national institute, to continue and extend the functions of the various existing academies.[21] In a later report on behalf of the Committee on Public Instruction, Condorcet showed that the only satisfactory method of determining the membership of such an academy is to leave the elections to the members themselves.[22] Article 298 of the Constitution, adopted August 22, 1795, declares:

> Il y a pour toute la République un Institut national chargé de recueillir les découvertes, de perfectionner les arts et les sciences.[23]

This differed from the former group of academies mainly in the unity of the academic body, which covered the whole range of knowledge (though the Académie Française was not represented), and the equality in number and privilege of the members resident in Paris and the non-resident members of the provinces.[24] Far from losing its prestige through the effects of the Revolution, the Academy of Sciences rose to its greatest success in the years following the Terror, and formed, with its sister academies, the chief connecting link between the modern democracy and the old régime.[25]

The National Institute, as thus constituted, lasted until 1803, when Napoleon Bonaparte again reorganized it. The members of the first class (Academy of Sciences) were grouped in two divisions, containing eleven sections in all. The two secretaries, no longer connected with any section, were made permanent. This organization, with no essential change, still remains in force. The law of 1803 suppressed the national associates, replacing them in the case of the Academy of Sciences by 100 correspondents (national and foreign), increased to 116 in 1899.

It is interesting to remember that Napoleon took an active part in the Academy of Sciences, of which he was elected a member in 1797. During the expedition to Egypt he invariably signed himself "Le membre de l'Institut, général en chef."[26] His appreciation of the importance of scientific research is amply illustrated by the distinguished company of investigators which he took with him on this expedition, where he organized the Institute of Egypt in Cairo, and proposed to establish an astronomical observatory.[27] The extensive and superbly illustrated report of his investigators on the antiquities of Egypt was the first great step in Egyptian archeology, leading to the brilliant labors of Champollion, Mariette and Maspero, and the dominance of the French school in Egypt even under British control.

In the great days of the First Empire began the brilliant period in the history of

21 Hippeau, "L'instruction publique en France pendant la révolution," Vol. I., p. 102.

22 *Ibid.*, p. 327.

23 Simon, "Une Académie sous le Directoire," p. 39.

24 Simon, *op. cit.*, pp. 44, 46, 50.

25 Maury, "L'ancienne Académie des Sciences," p. 1.

26 Simon, *op. cit.*, p. 40.

27 "Mémoires sur l'Egypte," Paris, An. VIII.

the Academy which Merz so justly emphasizes. With such members as Lagrange, Laplace, Legendre and Cauchy in mathematics; Messier, Arago, Lalande and Delambre in astronomy; Biot, Ampère, Fourier, Fresnel, Becquerel and Regnault in physics; Berthollet, Gay-Lussac, Dulong, Dumas and Chevreul in chemistry; Cuvier, de Jussieu, Lamarck and Geoffroy Saint-Hilaire in biology, and with others equally celebrated in other fields, it is not surprising that the Academy commanded the respect and the admiration of the civilized world.

Some of the elements which have entered into the success of the Paris Academy are not difficult to recognize: The sympathy and support of such statesmen as Colbert and Napoleon, who appreciated the fundamental importance of science to the nation, as Alexander the Great and the Ptolemies had done before them; the cooperative spirit which led the members to work together for a common cause; the perfection in the hands of the academicians of the powerful mathematical methods which contributed so largely to the application and widespread usefulness of Newton's discoveries; and the popularization of science and the diffusion of the scientific spirit through the brilliant writings of Cuvier, Laplace, Buffon, Fontenelle and many others. Far from disdaining the translation of technical papers into attractive literature, these great leaders set an example which was followed hardly less effectively, though in a different manner, by Davy and Faraday at the Royal Institution. Cuvier, above all others, represented the academic system at its best. In his eloquent Éloges on the most eminent scientific men of the day, he paints a picture of scientific investigation and progress with the hand of a practised artist. The wide field of science, and the rich results flowing from the labors of investigators skilled in many departments of knowledge, has never been more admirably depicted than in the discourses of this distinguished perpetual secretary.[28]

In Germany, the division of the empire into many kingdoms, preventing the centralization which has been so important a factor in France and England, and the prevailing influence of the universities as research laboratories, where every teacher is not only a scholar but a productive investigator, have stood in the way of the development of any such national institution as the Paris Academy of Sciences.

During the eighteenth century the great men of science, including Leibnitz, Euler, Haller, Tobias Mayer, Lambert, Olbers and Alexander von Humboldt, were widely scattered, and in most cases had little to do with the universities, although these were already distinguished for classical scholarship. But by the publication of his "Disquisitiones Arithmeticæ," and the invention of his improved method of calculating planetary orbits, Gauss, of the University of Göttingen, placed himself on a level with the great French mathematicians and inaugurated a new era in German science. By the use of this method, von Zach and Olbers were enabled to recover the first of the minor planets, Ceres, which had been lost on its approach to the sun. Gauss also introduced exact science into the university curriculum, but it was through the work of Jacobi that the great school of German mathematicians was set on foot a quarter of a century later. The contemporary

[28] For the data used in this account of the Paris Academy I am largely indebted to the work of Maury, Simon, Merz and Hippeau, already cited, and especially to the article by Darboux in "L'Institut de France," Vol. 2 (Paris, 1907). See also the useful series of articles by Dr. E. F. Williams on the Paris, Berlin and Vienna Academies in the *Popular Science Monthly.*

establishment of chemical laboratories by the universities, and the widespread influence of Liebig, Mitscherlich and Wöhler, in chemistry, and of Schleiden and Schwann in botany and zoology, determined for all time the place of the German university in science. Schleiden's cell theory of plant structure and growth was the source of a long series of discoveries, which established the supremacy of Germany in physiology.[29]

In spite of the unfavorable conditions already mentioned, four great academies have nevertheless arisen in Germany, those of Berlin, Munich, Leipzig and Göttingen. Among these, partly because of the leadership of Prussia in the German empire and partly from other causes, the Berlin Academy stands foremost. Founded in 1700 as the *Societas Regia Scientarium,* through the influence of Leibnitz and in accordance with his plans, it has contributed in the highest degree to the advancement of German scholarship. Its present designation as "Akademie der Wissenschaften" indicates the broad scope of its activities. The fifty regular members are divided into two classes, each of which consists of two sections, presided over by a permanent secretary. The first class comprises the sections of physics and mathematics, the second those of philosophy and history. The secretaries preside in turn at the meetings of the separate classes, and at the general meetings, which are held monthly. Each member receives an annual stipend of 900 marks, while the secretaries are paid larger salaries. There are also two positions carrying salaries of 12,000 marks each, filled by the astronomer and the chemist of the academy, and a dozen similar pensions which may be distributed at discretion.

In the early days of its history, the Berlin Academy devoted most of its resources to the establishment and maintenance of research laboratories and museums. Its headquarters were originally in the Berlin Observatory, which was conducted under the direction of the Academy, and it also brought together an anatomical collection, a mineralogical museum, and a zoological garden. Furthermore, the chemist of the Academy conducted his researches in a chemical laboratory provided for the purpose.[30] In 1809, when the University of Berlin was established to compensate for the loss of Halle by the treaty of Tilsit, these functions of the Academy were transferred to the university and have since remained under its direction. In an interesting and important manuscript by Wilhelm von Humboldt, entitled "Ueber die innere und äussere Organization der wissenschaftlichen höheren Anstalten in Berlin," his ideas on the relationship between the academy and the newly organized university are fully set forth. Schleiermacher had defined the university as a group of students, the academy as a group of investigators: the former concerned with the diffusion of knowledge, and the stimulation of scientific research, the latter with the development of scientific problems themselves. Humboldt believed the main distinction between the two bodies to lie in their form and their relationships rather than in their work. The university always remains in close relationship with practical life and the necessities of the state, since it is engaged in the practical task of educating the youth of the nation, while the academy is concerned solely with knowledge.

> When only the function of teaching and disseminating knowledge is assigned to the university and its promotion to the academy, injustice is manifestly done the former.[31]

[29] See Merz's "History of European Thought," Vol. 1, Chap. 2.

[30] See Harnack's great "Geschichte der Berliner Akademie der Wissenschaften."

[31] Paulsen, "The German Universities," trans. by Thilly and Elwang, p. 53.

Whereas the university teachers are under common bonds only in the matter of discipline, and are quite independent of one another in other respects, the academy is a society each member of which must submit his work to the judgment of all. Hence, he insists, the idea of an academy as the highest and ultimate freehold of knowledge, and as a corporation which is more independent than any other of the state, must be maintained.

In Humboldt's view, a close interchange of activities between academy and university should be provided for. Each academican must have the right to lecture at the university without going through the ordinary preliminaries, and without involving any direct connection with it. Many scholars should be both university professors and academicians, but both institutions should have other members who belong to it alone. The academy must be free to choose its own members, subject only to the approval of the government, while professors in the university should be appointed exclusively by the state.[32]

In spite of the transfer of some of its principal departments to the University of Berlin, the Berlin Academy has by no means relinquished its important object of carrying on large research projects. As already stated, it still has an endowed professorship of chemistry, recently held by van't Hoff, and now by Fischer, and a professorship of astronomy, held by Auwers. Both of these investigators pursue their researches under the auspices of the Academy. The great work upon which Professor Auwers is engaged is characteristic of many of the larger undertakings of the German academies, to which they devote nearly half of their available funds. This is the "Geschichte des Fixsternhimmels," an immense catalogue of star positions based upon the observations of many astronomers. Similar undertakings by the Berlin Academy in other fields are the "Corpus inscriptorum græcarum" and the "Corpus inscriptorum latinarum." The preparation of a great edition of Aristotle's works, begun by the Berlin Academy in 1821 and finished in 1909, is cited by Diels as a most striking illustration of the advantage of academic continuity, with which no individual can hope to compete.[33] For such an undertaking, which we have come to regard as characteristically German, an organized body like an academy of sciences possesses, not merely the advantage of continuity, but that which results from the combined experience and the wide range of vision brought to bear through the cooperation of many eminent authorities. An academy may also command far more extensive material than would fall within the reach of the individual worker. This phase of academic activity, practised in different forms in the Museum of Alexandria and, in the preparation of national dictionaries, by the Académie Française and the Accademia della Crusca, is also illustrated in England by the Royal Society's "Catalogue of Scientific Papers." Our own National Academy has yet to take any steps in this direction.

The importance attached to this form of academic work in Berlin is clearly illustrated in the plans of the new academy building, for a set of which, I am indebted to the kindness of Professor Diels. This building, which is being constructed in connection with the new Royal Library, is probably more perfectly adapted for academic purposes than any other building now in use, as it was especially designed

[32] Lenz, "Geschichte der Universität Berlin," Bd. I., pp. 186–188.

[33] Diels, "Die organisation der Wissenschaft," in "Die Allegemeinen Grundlagen der Kultur der Gegenwart," 2d ed., p. 667.

for the work to be carried on in it.[34] The plans show that one room each is to be devoted to the *Corpus medicorum Græcorum,* the *Acta Borussia,* and the Plant Kingdom, three rooms to the *Corpus inscriptorum Latinarum,* four to the Oriental Commission, four to the Egyptian Dictionary, eleven to the *Inscriptiones Græcæ,* eleven to the German Commission, two to the edition of Leibnitz's collected works, seven to the History of the Fixed Stars. In addition to all of these rooms for special research, there are the great "Fest Saal," separate meeting rooms for the two classes of the Academy, a general meeting room for both classes together, a large anteroom, a demonstration room, seven editorial rooms, four secretaries' offices, offices for the registrar, the recorder and the chancellor, a reading-room and large library and stack room, a correspondence room, an instrument room, a photographic laboratory, and various other offices, kitchens, servants' rooms, etc.

It is a significant fact that Merz, after devoting an eloquent chapter to the evolution of science in France under the stimulus of the Paris Academy, barely mentions the German academies when discussing the progress of science in that country. The reason, as we have already seen, lies in the predominating influence of the universities in the development of German scientific life and thought. With every teacher an investigator, every university a laboratory of research, and with the powerful aid of the state encouraging in every possible way the prosecution of investigation no less than the instruction of students, it is easy to see how the universities obtained their ascendancy in the field of science, or rather in the broad field of *Wissenschaft,* for in Germany the same spirit of research has permeated every department of knowledge. The wide distribution of the universities and their considerable number, together with the free interchange of professors and students, have worked against centralization, and have served to create a cosmopolitan spirit in striking contrast with that which obtains in France. One can hardly fail to believe that no single influence could be more effective than the universities for the development of the latent capacity of a nation for scientific research. But while the German academies have doubtless suffered by contrast with the universities, a survey of the intellectual progress of Germany should by no means overlook the invaluable services they have rendered.

It would seem, however, that these services might have been even greater if a larger number of the scientific men of the nation could have taken an active part in the work of the academies. As at present constituted, the membership of these bodies is extremely limited, and the requirement that each member must reside within a very short distance of the seat of the academy, so that he may be able to attend the meetings regularly, is in striking contrast with the wider membership and freer interchange which seem to have been essential elements in the extraordinary development of the university system.

When we pass to England, and examine into the conditions of intellectual progress, we find a fundamentally different condition of affairs. This reflects the natural characteristics of the English people, just as the university system of Germany and the academic activities of France illustrate the essential qualities of these nations. Merz's picture of the growth of scientific research in England is in some respects a somber one. In his view the Royal Society appears to have played no part in advancing the

[34] Most of the European academies are housed in palaces or similar buildings formerly used for other purposes.

intellectual life of the nation and the Royal Institution, as well as Oxford and Cambridge, fare little better at his hands.

Now no one will attempt to deny that the characteristic quality of British science has always rested in the individual, and that organized efforts there have played a less conspicuous part than in France or in Germany. During a large part of their history, Oxford and Cambridge have done little for research, though the past half century has seen an extraordinary change in this respect, particularly in the case of the Cavendish laboratory, whose succession of brilliant leaders can hardly be matched in the history of any other university laboratory. Men whose names are famous in science have sprung up in the most unexpected places, without ancestry, training or encouragement to account for the dominant influence they have exerted on the scientific thought of the world. A notable illustration of this kind is afforded by Faraday, whose obscure origin, extreme poverty, and lack of the assistance of schools, were most fortunately offset by his transcendent genius and by the influence of Davy, whose lectures at the Royal Institution soon transformed the bookbinder's apprentice into Davy's brilliant successor. Darwin, though of distinguished ancestry, was another English "amateur" whose work was done apart from the universities. A host of others might be mentioned, whose extraordinarily original contributions to scientific thought have found few equals in other lands. For the most part, they have worked alone and sometimes unaided, and their great results have been achieved in spite of conditions which may appear unfavorable and discouraging. But in my opinion the Royal Society and the Royal Institution, not to speak of other important agencies, such as the societies devoted to special branches of science, have exercised in England a profoundly favorable influence which can not be ignored.

In failing to take note of this in his classic work, Merz seems to exhibit some traces of that pessimistic quality which is not infrequently encountered in English life. It is to short-sightedness of the government and to individual conservatism, tinctured with pessimism, that I should be inclined to charge that lack of support of scientific men of which Merz so feelingly complains, rather than to the Royal Society and other organized bodies for the promotion of science. As a matter of fact, it is easy to show that these institutions have exerted a powerful stimulus, without which the progress of science in England undoubtedly would have been delayed.

In the first place, the Royal Society has extended the distinction and privileges of its fellowship to a much larger number of investigators than have been similarly honored by the continental academies.[35] Every investigator in science will understand and appreciate the benefit which such recognition entails. Most of all the obscure individual worker, unnoticed and unsupported by the universities, but wholly devoted to the pursuit of science, must benefit by such moral support. On the continent I have known investigators of this type, not connected with a university, and receiving no aid or encouragement from neighboring university men, who could not be recognized by election to the academies because of their limited membership or their fixed traditions. In England such men would have been received into the Royal Society, which would have been glad to publish their papers as Fellows and to aid them in other ways.

A notable illustration is afforded by the case of Newton, elected a fellow of the

[35] Fifteen new members are elected annually, making a total membership of 477 (Jan. 1, 1913).

Royal Society on January 11, 1671, and subsequently its president for the long period of twenty-four years. A month following his election, Newton communicated to the Society his discovery of the composite nature of white light, which, when published in the *Philosophical Transactions,* was the first of his productions to appear in print. In expressing his thanks to the Society, Newton remarked:[36]

> It was an esteem of the Royal Society for most candid and able judges in philosophical matters, that encouraged me to present them with that discourse of light and colors, which since they have so favorably accepted of, I do earnestly desire you to return them my most cordial thanks. I before thought it a great favor to be made a member of that honorable body, but I am now more sensible of the advantage: for believe me, Sir, I not only esteem it a duty to concur with them in the promotion of real knowledge, but a great privilege, that, instead of exposing discourses to a prejudiced and censorious multitude (by which means many truths have been baffled and lost), I may, with freedom, apply myself to so judicious and impartial an assembly.

Leuwenhoeck, "the father of microscopical discoveries," who communicated no less than 375 papers and letters to the Society during a period of fifty years, bequeathed a collection of microscopes "as a mark of my gratitude, and acknowledgment of the great honor which I have received from the Royal Society."[37]

When the Royal Observatory was established at Greenwich, the government failed for a period of nearly fifteen years to furnish it with a single instrument. In this extremity Flamsteed appealed to the Royal Society, with the following result recorded in the minutes:

> It was ordered that the astronomical instruments belonging to the Society be lent to the Observatory at Greenwich, and that Mr. Hooke's new quadrant be forthwith finished at the charges of the Society.[38]

Examples of this nature might be multiplied indefinitely, but a single case will suffice, since no more striking instance of the splendid results directly due to the encouragement and aid of the Royal Society could be asked than that illustrated in the life and work of Sir William Huggins, one of the founders of astrophysics, and a typical example of the English "amateur" investigator.[39] Sir William, to whose addresses as president of the Royal Society we shall have occasion to refer later, was not a university man. With his accomplished wife as his only assistant, he lived and did all his work at Upper Tulse Hill, well removed from the bustle of Piccadilly on the Surrey side of the Thames. It is more than probable that without the stimulus and aid of the Royal Society much of his great work could not have been done. For it was on returning home from a Royal Society meeting in company with his friend Miller that he first conceived the idea of observing the spectra of stars, and it was with telescopes and other instruments loaned to him by the Society that his classic observations were made. In spite of fogs and clouds of London smoke, he continued his work up to the very end of his long life, dividing his allegiance to science only between his astrophysical investigations and the development of the Royal Society, of which he was for forty years a leading Fellow.

Thus, in spite of that early poverty which prevented the Royal Society from publish-

36 Weld, "History of the Royal Society," Vol. I., p. 237. Brewster's "Life of Newton" gives an interesting account of Newton's relations with the Royal Society and his plan for its improvement (Vol. I., p. 102).

37 Weld, *ibid.,* p. 245.

38 Weld, *ibid.,* p. 255.

39 It is hardly necessary to say that the term "amateur" is used here to denote one who works in science for the pure love of the subject, and not in the sense of dilettante.

ing the "Principia" of Newton, it has lent its powerful aid and support to many a British investigator, who without it would have been absolutely isolated. Its large collection of instruments, the accumulation of more than two centuries, is freely placed at the disposal of those who need them. Its *Philosophical Transactions* and *Proceedings* have furnished the most desirable means of publication for an enormous mass of scientific literature. Its meetings bring together every Thursday at Burlington House the leading scientific men of the kingdom, and furnish an opportunity for stimulating interchanges of view which have played a great part in scientific progress. Its various gold medals, impartially bestowed at home and abroad, in recognition of advances in science, have been powerfully supplemented by financial assistance to investigators from the Government Grant Fund of £4,000 per annum, which is administered by the Society. To its influence is largely due the high standard of efficiency maintained by the government in its appointment of astronomers royal and other directors of the scientific research of the nation. When the government decided to establish a national physical laboratory it turned at once to the Royal Society, to which it delegated the planning and control of this great institution. Its *Catalogue of Scientific Papers*, continued as the *International Catalogue of Scientific Literature*, has contributed in a most important way to the accessibility and usefulness of the literature of science, and is indispensable to every investigator. It has supplied both money and instruments to scientific expeditions sent to all parts of the globe, and provided for the suitable reduction and discussion of the observations obtained. It has aided the government of India in the work of the Indian Meteorological Department and participated with the meteorological office in the direction of the work of the Kew and its sister observatories. The reports of the Sleeping Sickness Commission have advanced in an important degree our knowledge of tropical diseases. In fact, one could point to an almost unlimited number of illustrations of the beneficent activities of the Royal Society as the leading representative of British research, and as one of the most powerful factors in broad projects of cooperation, such as those of the International Association of Academies.

Unlike the academies of St. Petersburg, Berlin, Vienna and Stockholm, which maintain large research laboratories or support research professorships, the Royal Society has no laboratories of its own. Closely allied with it, however, is the Royal Institution, formerly known as "the workshop of the Royal Society." No laboratory in existence can match its extraordinary record, accomplished at an almost incredibly small cost.[40] When one recalls Young's great work in laying the foundation of the wave-theory of light, not to speak of his success in discovering the first clue to the translation of Egyptian hieroglyphics; Davy's long series of discoveries in chemistry, and his brilliant lectures and demonstrations; Faraday's unparalleled achievements in physical and chemical research, and the dignity and luster he imparted to the popular presentation of scientific results to a general audience; Tyndall's success in the same lecture-hall, and his services in popularizing science in the United States; and the long series of important investigations, especially in the fruitful field of low temperature phenomena, which we owe to Dewar, who has now occupied the chair of chemistry even

[40] Dewar, address as president of the British Association, Belfast, 1902, p. 11.

longer than Faraday: these form a record remarkable in the annals of science, with returns so rich as to be worthy of the expenditure of almost any sum. But even this long list does not represent the total product of the laboratory, where such eminent leaders as Lord Rayleigh and Sir Joseph Thomson have also conducted investigations of the first importance. So far as my own observations have gone, no other laboratory holds such an atmosphere of research or stimulates so powerfully the imagination of the investigator. I shall have occasion later to refer to the equally remarkable success of the Royal Institution in diffusing and popularizing knowledge through its course of experimental lectures.

Academies of the first class are so numerous that only a few of the oldest organizations, whose work bears directly upon the problems of our own National Academy, can be mentioned in this paper. I hope to have opportunity at some future time to describe the work of such influential bodies as the Vienna Academy, which has founded a Radium Institute and taken steps which should result in the establishment of a Solar Observatory; the Stockholm Academy, entrusted with the responsibility of awarding the Nobel Prizes in physics and chemistry; the Amsterdam Academy, focus of the great research work of Holland; and many other academies of the highest rank representing the various nations of Europe. For the present I must limit attention to a group of institutions which are sufficient to typify the wide range of academic activities. However, a word must be added regarding the St. Petersburg Academy, established by Catherine I. on the plans of Peter the Great in 1725, because of its special plan of organization. The president, director and fifteen members are paid annual stipends ranging from one thousand to three thousand dollars, and provided with dwelling houses. The great academy building, with its library of over 36,000 books and manuscripts, contains large laboratories in which investigations are constantly in progress. The extensive publications include researches in every field of knowledge and exhaustive memoirs on the topography, geography and history of Russia and the manners, customs and languages of its various peoples.

From this survey of the work of a few of the leading academies and allied institutions, we see that original investigations have played a large part in their activities, from the days of the great museum at Alexandria to the present time. In certain instances, illustrated in the history of the University of Berlin, some of the work of investigation has been transferred from the academies to the universities, but without interrupting the larger activities of the academies in the same field. Again, in cases like that of the Royal Society, the development of a closely allied laboratory of research, such as that of the Royal Institution has partially supplied the place which a laboratory under the exclusive control of the Society might have held. The essential thing to note is the advantage which results from the organic relationship of an academy with a laboratory for the production of new knowledge. An academy will reach its greatest influence, and serve its most useful purpose in stimulating the work of its members, when it is recognized as an institution primarily "for the increase" rather than "for the diffusion of knowledge among men."

In the field of publication, the great academies of former times were predominant factors, so much so that we owe to their printed pages the great volume of the original contributions of the earlier days of science. With the rapid extension of

the facilities for research, and the extensive ramifications of science into special fields, the societies and journals devoted to particular lines of research naturally arose and multiplied. The prestige of such publications as the *Proceedings* and *Transactions* of the Royal Society fortunately enables them to hold their own, in spite of the competition of so many journals devoted to special subjects. And the opportunity afforded by academies for the publication of extended memoirs beyond the range of ordinary periodicals, is universally appreciated. As regards shorter communications, the peculiar claims of the special journals, which have been proved by time to serve the purposes for which they were designed, would naturally receive consideration in elaborating any new plan of academic publication to meet existing needs. This subject will be more fully considered in a later paper.

In the management and distribution of trust funds for research, the loan of instruments, the award of prizes, and especially in the advice of governments and individuals as to the best means of initiating and conducting scientific enterprises, national academies occupy a position which private foundations can hardly hope to rival. The value of advice received from a body of the highest reputation and prestige is greatly enhanced, because of the increased probability that it will be heeded and carried into effect. For a similar reason, recognition of individual achievement through the award of prizes or election to membership acquires its greatest weight when received from such a body.

After reviewing all of the activities which we see so diversely exemplified by the national academies of different countries, the conviction is forced upon one that the first and best object of these bodies must always be to uphold the dignity and importance of scientific research, and to diffuse throughout the nation a true appreciation of the intellectual and practical benefits which will inevitably result from its support and encouragement. But to accomplish great results in this field, an academy must enjoy the active cooperation of the leaders of the state. To appreciate this, we have only to remember the many striking illustrations afforded in the history of civilization. What was done by Alexander the Great and the Ptolemies for Egypt, by the house of Medici for Italy, by Richelieu, Colbert and Napoleon for France, can be done for other nations by living statesmen to-day. In the midst of his campaigns Napoleon never forgot the paramount claims of science and the arts. Writing to the astronomer Oriani from Milan, which he had entered in triumph, Napoleon said:

> The sciences which do honor to the human mind and the arts which embellish life and perpetuate great achievements for posterity, should be especially honored under free governments.
>
> . . . I invite the scholars to meet and to give me their opinions as to the means that should be taken, and the needs to be fulfilled, in order to bring new life and activity into the sciences and the fine arts. Those who wish to go to France will be received with distinction by the government. The French people set a higher value on the acquisition of a skilled mathematician, a celebrated painter or a distinguished man of any profession, than upon the possession of the largest and richest city.[41]

That such views are still shared by modern rulers is illustrated by the recent establishment of a great institution for scientific research by the Emperor of Germany.

This article can not be better closed than by a quotation from Laplace, the most distinguished member of the Paris

[41] Maindron, "L'Académie des Sciences," p. 205.

Academy in its brilliant days under the first empire.

Nature is so varied in her manifestations and phenomena, and the difficulty of elucidating their causes is so great, that many must unite their knowledge and efforts in order to comprehend her and force her to reveal her laws. This union becomes indispensable when the progress of the sciences, multiplying their points of contact, and no longer permitting a single individual to understand them all, throws upon a group of investigators the task of furnishing the mutual aid which they demand. Thus the physicist appeals to the mathematician in his efforts to arrive at the general causes of observed phenomena, and the mathematician in his turn consults the physicist, in order to render his investigations useful by practical applications, and in the hope of opening up new possibilities in mathematics. But the chief advantage of academies is the philosophic spirit which must develop within them, thence diffusing itself throughout the nation and permeating every interest. The isolated scholar may yield with impunity to the tendencies of the systematist, since he hears only from afar the criticism that he arouses. But in an academy the impact of such tendencies ends in their destruction, and the desire for mutual conviction necessarily establishes the rule of admitting only the results of observation and calculation. Furthermore, experience has shown that since the origin of academies the true spirit of philosophy has prevailed. By setting the example of submitting everything to the test of severe logic, they have overthrown the preconceived notions which too long dominated science, and were shared by the ablest minds of previous centuries. Their useful influence on public opinion has dissipated errors greeted in our own time with an enthusiasm which would have perpetuated them in earlier days. Equally removed from the credulity which denies nothing and the conservatism which would reject everything that departs from accepted ideas, they have at all times wisely awaited the result of observation and experiment on difficult questions and unusual phenomena, promoting them by prizes and by their own researches. Measuring their approval no less by the greatness and difficulty of a discovery than by its immediate utility, and convinced, by many examples, that what appears to be least fruitful may ultimately yield important consequences, they have encouraged the pursuit of truth in all fields, excluding only those which the limitations of the human understanding render forever inaccessible. Finally, we owe to them those great theories, elevated by their generality above the comprehension of the layman, which through numerous applications to natural phenomena and the arts, have become inexhaustible sources of happiness and enlightenment. Wise governments, convinced of the usefulness of scientific societies, and regarding them as one of the principal causes of the glory and prosperity of empires, have established such bodies in their very midst, in order to profit by their counsel, which has often brought lasting benefits.[42]

George Ellery Hale

THE BALTIMORE MEETING OF THE NATIONAL ACADEMY OF SCIENCES

The National Academy of Sciences will meet November 18 and 19 at the Johns Hopkins University, Baltimore. The council will meet the evening before; and on these two dates there will be public sessions with papers by members of the academy and others.

A preliminary program of these papers is as follows:

Henry Fairfield Osborn: *Final Results on the Phylogeny or Lines of Descent in the Titanotheres.*

Thomas H. Morgan: *The Constitution of the Chromosomes as Indicated by the Heredity of Linked Characters.*

The paper is a discussion of recent discoveries in sex-linked inheritance and their bearing on the mechanism of heredity and the constitution of the chromosomes. Starting with the assumption that Mendel's law of segregation finds a plausible explanation in the processes known to occur in the ripening of the egg and sperm, an attempt is made to analyze the ratios that appear in sex-linked inheritance—ratios that depart from those that rest on the assumption of independent assortment of pairs of characters. It is shown how these departures find a reasonable explanation on the assumption that interchange takes place between members of the same pair of chromosomes. The Mendelian ratios, on the

[42] "Exposition du Système du Monde," *Oeuvres*, Vol. VI., p. 418.